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Published in:
Proceedings of the 8th Symposium of The Pharmaceutical Solid State Research Cluster

Publication date:
2014

PHYSICAL CHARACTERIZATION OF PHOTOCROSSLINKED POLY(VINYL PYRROLIDONE) (PVP) HYDROGELS FOR DRUG DELIVERY

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PURPOSE

The work was aimed to elucidate the mechanical and structural properties of hydrogels of poly(vinylpyrrolidone) (PVP) prepared by UV photocrosslinking in order to design a drug delivery system for biomacromolecules. Rotational rheometry was employed to determine the average mesh size of the network. Finally a model was developed to correlate the nuclear magnetic resonance (NMR) relaxation spectra and estimate mesh size distribution.

MATERIALS AND METHODS

Materials

The tests were performed on hydrogel specimens prepared as follows. Solutions containing linear PVP (K90, Sigma Aldrich), DI water (99.1% v/v) and H_2O_2 (0.9% v/v) were prepared with various concentrations of polymer (10, 20, 30% wt). Additional 30% PVP solutions were prepared double and triple amounts of H_2O_2 (later referred as 30%+2H and 30%+3H). The mixtures were casted into cylindrical metal moulds (1 mm in depth, 15 mm in diameter). The films were exposed to UV light (UVB+UVC 29-32 mJ/cm^2) in a photoreactor (BS-02 Dr. Gröbel UV Elektronik, Germany) for 22, 33 and 44 min. After photoreticulation, and prior to the analysis, all the considered gels were collected and dipped in DI water to extract the uncrosslinked polymer and excess of crosslinker. After 24 hours, gels swelled considerably with a water uptake equal up to 30 times the dry weight.

Rheology

The mechanical properties of PVP hydrogel were calculated by small-amplitude oscillatory shear experiments. The tests were performed by using a stress-controlled rheometer (HAAKE Rheostress RS-150) in parallel plate geometry (15 mm of diameter). Each sample was submitted to a frequency sweep test (FS) (t=1 Pa f=1Hz) where the *storage modulus* G' and the *loss modulus* G" were measured as a function of the frequency ω (0.01-10 Hz) of the sine wave stress applied to the material. The resulting mechanical spectra were fitted with the generalized Maxwell model.

Based on the fitting results, the average mesh size of the polymeric network, ξ_a, was estimated according to the theory of Flory [1]:

$$\xi_a = \sqrt[3]{\frac{6}{\pi \rho_x N_A}} \quad (1)$$

Where N_A is the Avogadro constant and ρ_x is the crosslinking density.

NMR spectroscopy

In these analyses the relaxation of the hydrogen magnetic moments is recorded over time. By knowing the volumetric concentration of the polymer ν_p in the swollen gel, the function $f(\nu_p)$ can be calculated from the following equation:

$$f(\nu_p) = \sqrt{\frac{(1 - 0.58\,\nu_p)(1 - \nu_p)}{\nu_p} \frac{C_0}{C_1}} \quad (2)$$

C_1 and C_0 are geometrical constants [2]. The average relaxation time, $\langle T_2 \rangle$, and ξ_a are known and can be combined in the Chui model [3]:

$$\left\langle \frac{1}{T_2} \right\rangle = \frac{1}{T_{2,H_2O}} + \frac{2\mathcal{M}}{\xi_a \cdot f(\nu_p)} \quad (3)$$

From eq. (3) $\mathcal{M}$ is calculated and a distribution of ξ can be computed.

RESULTS AND DISCUSSION

In figure 1a, ξ_a is plotted as a function of the irradiation time for different PVP concentrations. In all the cases the mesh size decreases with irradiation time, meaning that the crosslinking reaction strongly depends on the UV dose. In figure 1b, a ξ_a vs UV time profile is presented for 30% PVP and different crosslinker concentrations. For samples 30+2H and 30+3H an increase of irradiation time brings to a dramatic thickening of the polymer network. In figure 2 an example of mesh size distribution is shown (PVP 20% 22 min). From the NMR study all the gels were resulted having a regular network, characterized by a monodisperse distribution of mesh sizes.

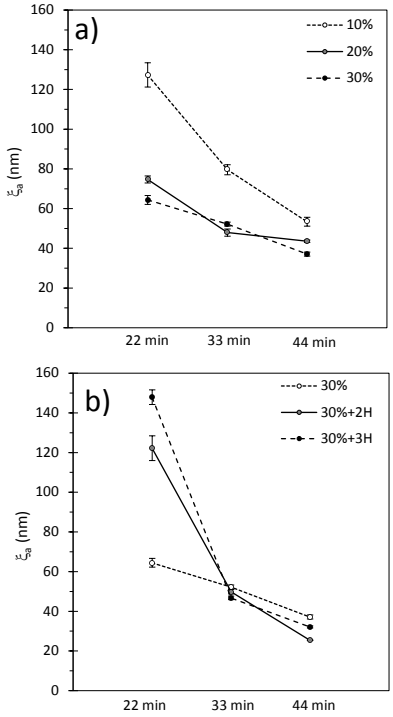

Fig. 1: Average mesh size as a function of UV exposure time for gels (a) 10, 20, 30% PVP and (b) with a different concentrations of crosslinker.

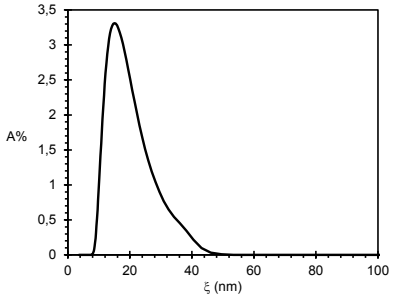

Fig. 2: Mesh size distribution for the gel 20% with 22 min irradiation, assuming an average value of ξ_a= 14.33 nm.

CONCLUSIONS

The present study shows that photocrosslinked PVP hydrogels exhibit mesh comparable to the size macromolecular therapeutics.

CHALLENGES AND FUTURE WORK

A release test of a model macromolecule will be performed to estimate the diffusion coefficient in the hydrogels.

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